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Use of Groundwater for Irrigation: Seward County, Nebraska

J.M. Jess
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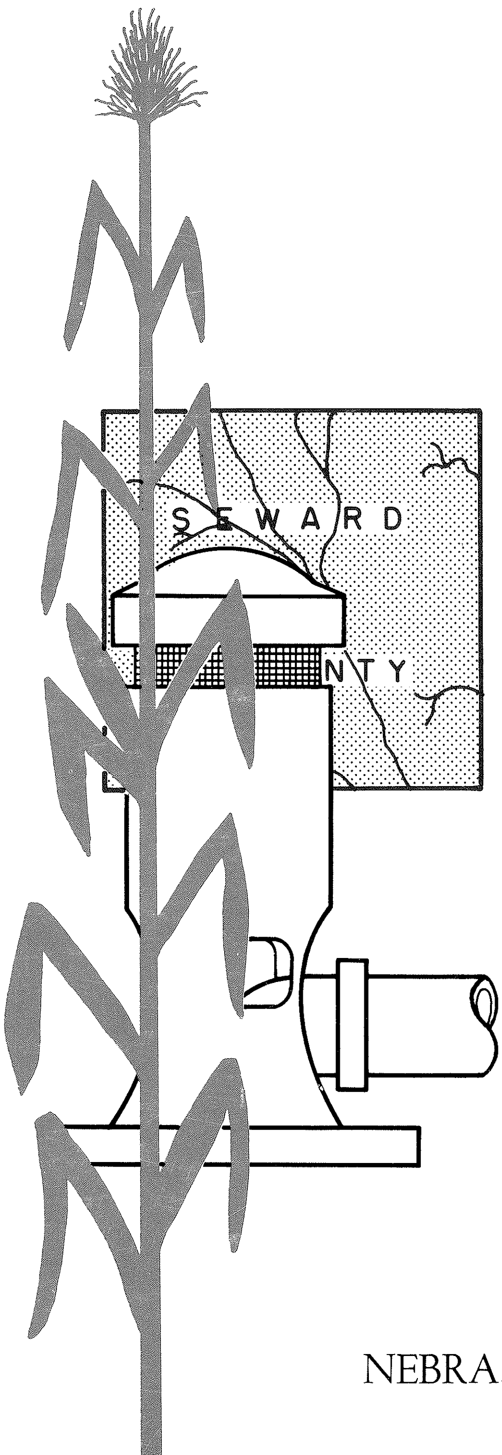

USE OF GROUNDWATER FOR IRRIGATION,

SEWARD COUNTY, NEBRASKA

by J. M. JESS

NEBRASKA WATER SURVEY PAPER 25

UNIVERSITY OF NEBRASKA
CONSERVATION AND SURVEY DIVISION

USE OF GROUNDWATER FOR IRRIGATION, SEWARD COUNTY, NEBRASKA

By

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USE OF GROUNDWATER FOR IRRIGATION, SEWARD COUNTY, NEBRASKA

By
J. M. Jess

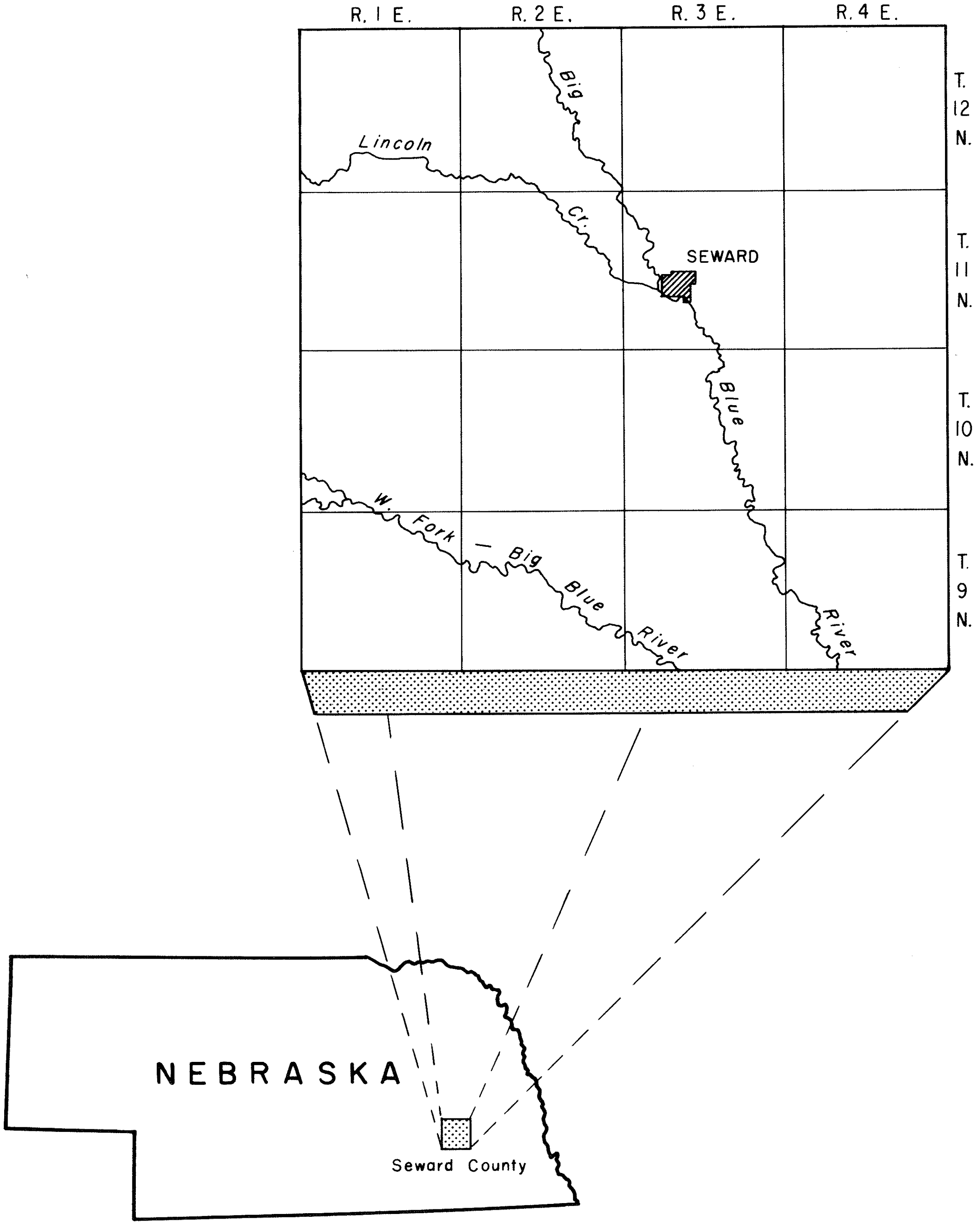
INTRODUCTION

Irrigation is the principal use of groundwater in Seward County. Domestic, stock, and public supply requirements additionally contribute to the total demand for groundwater.

Increased groundwater use has resulted in a general decline of groundwater levels (3 to 10 feet), mostly in upland areas. These declines, and the consequent greater pumping lifts and decreased well yields, have been the cause of public concern. Such declines emphasize the need for groundwater management conservation practices.

Pump irrigation has developed rapidly since 1950 when about 2,250 acres were irrigated. Approximately 56,000 acres were irrigated in 1968 from about 550 wells. The rate of irrigation-well installations and the amount of undeveloped, potentially irrigable land suggest that more land will be placed under pump irrigation in the future. Supplemental pump irrigation has made possible a stable, expanding agri-economy free from crop failure due to drought.

Seward County is in southeastern Nebraska (Figure 1). The county is nearly square and has an area of 572 square miles (366,080 acres). Groundwater in sufficient quantities for pump-irrigation demands is limited almost entirely to the area west



SEWARD COUNTY LOCATION MAP

FIGURE 1

of the Big Blue River. The scope of this study is limited to this area--about three-fifths of the county.

Because irrigation practices and system designs are quite uniform, managerial differences in farming practices are not great. A typical pump-irrigation installation consists of a 36-inch hole, gravel-packed back to an 18-inch inside diameter concrete or steel casing, equipped with an 8-inch discharge turbine pump. The pump is powered with either an electric motor or an internal-combustion engine utilizing natural gas, propane gas, diesel fuel, or gasoline. Pumping lifts, except for valley wells, range from 60 to 125 feet. Currently, each well irrigates approximately 95 to 100 acres of cropland.

Objectives and Acknowledgments

An extensive survey of irrigation practices was conducted in Seward County prior to, during, and after the 1968 irrigation season. This survey was made as part of an effort to determine the hydrologic characteristics of the principal aquifer, the quantity of groundwater pumped during the 1968 irrigation season, and the economic effects of groundwater irrigation. This report discusses the results of only the later two items.

The author wishes to express his appreciation to several individuals who gave him advice and assistance during various phases of his investigation. Professors R. N. DeVries and M. Baker, University of Nebraska, acted as co-advisors in criticizing the writer's Master's degree thesis, of which this publication was a portion. Considerable guidance in methods and

techniques was offered by Professors P. E. Fischbach, D. D. Axthelm, and R. R. Marlette, University of Nebraska. Much cooperation was given by L. L. Young, Seward County Extension Agent. The Seward County Irrigation Association generously lent equipment to facilitate the field work. K. E. Logan, State-Federal Division of Agricultural Statistics, and C. F. Keech, U. S. Geological Survey, made a great deal of information available and discussed its application to the study with the author.

Procedure

All of the field data upon which this study is based were collected during the summer and fall of 1968 and the early winter (January and February) of 1969. Well discharge and drawdown tests were conducted at 40 irrigation well sites. Also, the total hours of pumping were recorded on calendars furnished to the irrigators or were calculated from electric, natural gas, or engine meter readings. The procedure used to measure the discharge and drawdown, as well as a table showing these data, is given in the Appendix.

Data for the economic portion of the study were obtained by interviewing 16 farm operators. These data were collected in the summer of 1968 and the early winter of 1969. Also, information from records of the State-Federal Division of Agricultural Statistics was utilized.

Well-Numbering System

Wells are numbered in this report according to their location within the system of land subdivision of the U. S. Bureau of Land Management. The first numeral in the number indicates the township; the second, the range; and the third, the section. The letters that follow the section number indicate the position of the well within the section. Subdivisions of a section are lettered "a," "b," "c," and "d" in a counterclockwise direction, starting in the northeast quarter of a section. The first letter indicates the 160-acre tract; the second letter, the 40-acre tract; and the third letter, the 10-acre tract. Figure 2 illustrates this system for a hypothetical well.

DETERMINATION OF GROUNDWATER USE

Precipitation is the ultimate source of groundwater in Seward County. Part of the precipitation runs off the land surface to streams, part evaporates, and a portion not used by growing plants infiltrates the soil and moves downward to the water table. The groundwater reservoir is so large, volumetrically, that it is little affected by variations in the rate of annual precipitation. For this reason, the reservoir is dependable as a source for irrigation. The groundwater reservoir stores water during periods of surplus and releases it to springs, perennial streams, seeps, vegetation through transpiration, evaporation from soils, and wells.

Although adequate supplies of groundwater occur throughout the study area, a general lowering of the water table (3 to 10 feet) during the past 10 to 15 years has been observed. This decline has resulted because withdrawal from the groundwater reservoir has exceeded inflow to the reservoir. Total ground-

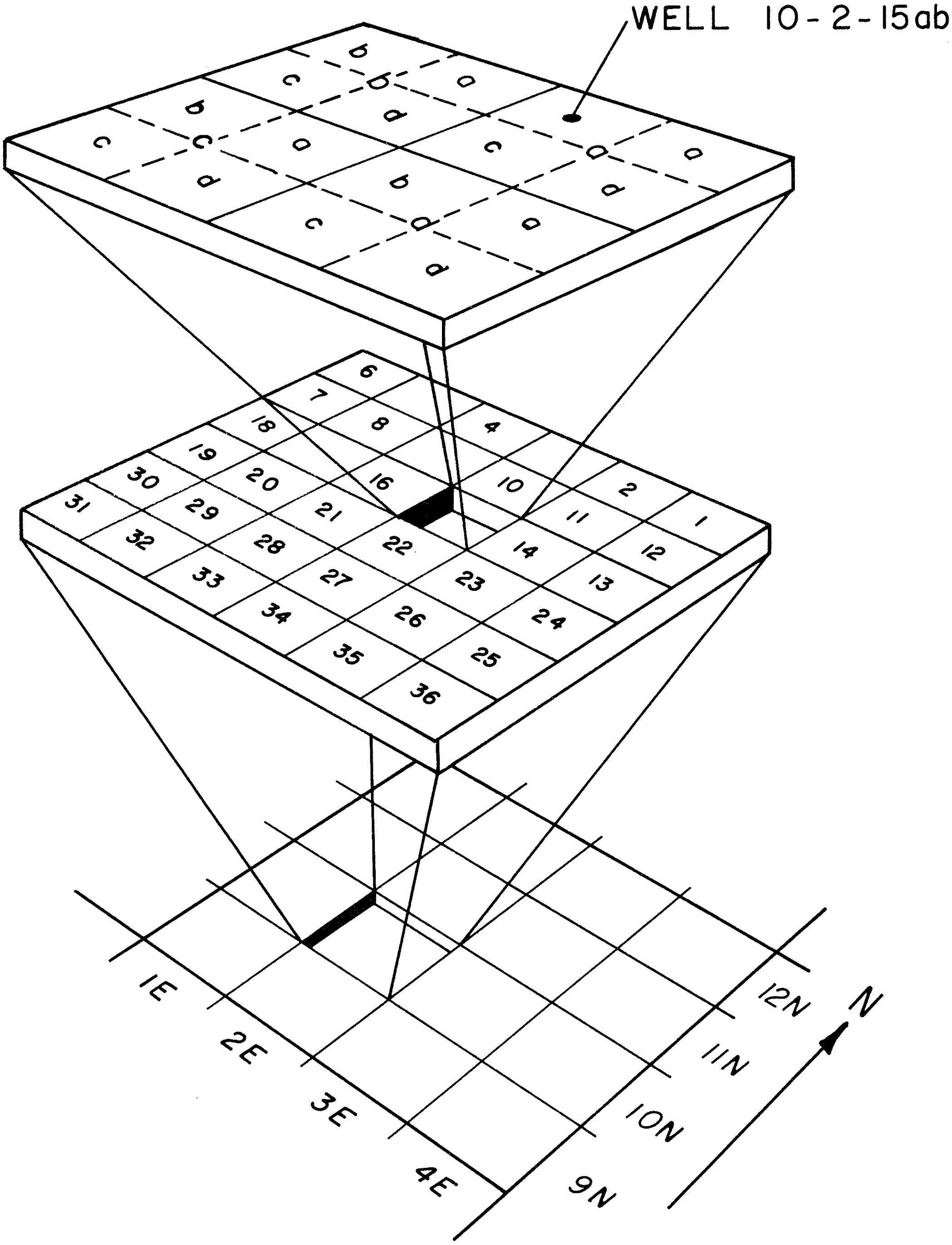


ILLUSTRATION OF WELL-NUMBERING SYSTEM

FIGURE 2

water in storage has decreased in proportion to the water-table decline. This decrease has resulted from large withdrawals for irrigation. The well hydrograph of Figure 3 shows a marked decline in the water level in this well since 1955. The decline is principally due to withdrawal of groundwater by wells.

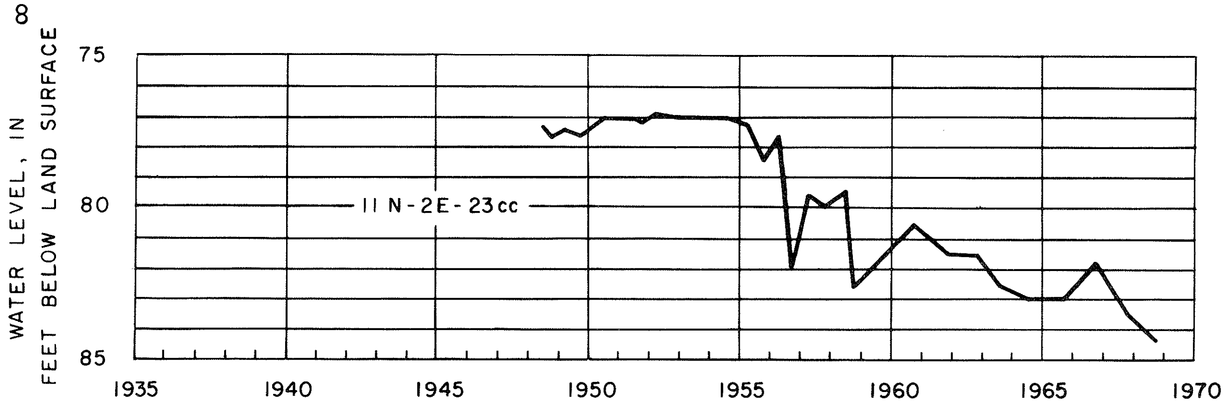
Prior to 1950 fewer than 20 irrigation wells existed in the county. Well installations increased during the dry years of the middle 1950's because supplemental irrigation convinced dryland farmers that it made the difference between crop failure and success. Figure 4 demonstrates irrigation-well installation over time and especially illustrates the accelerated rate of well installation in the mid-1950's.

1968 Groundwater Pumpage for Irrigation

The 1968 irrigation season began in mid-June, but was temporarily halted in late July because of abundant rainfall. Some irrigators resumed pumping in mid-August, but by early September the irrigation season had been concluded. Approximately 55,600 acres of corn, grain sorghum, and various other crops were irrigated with groundwater.

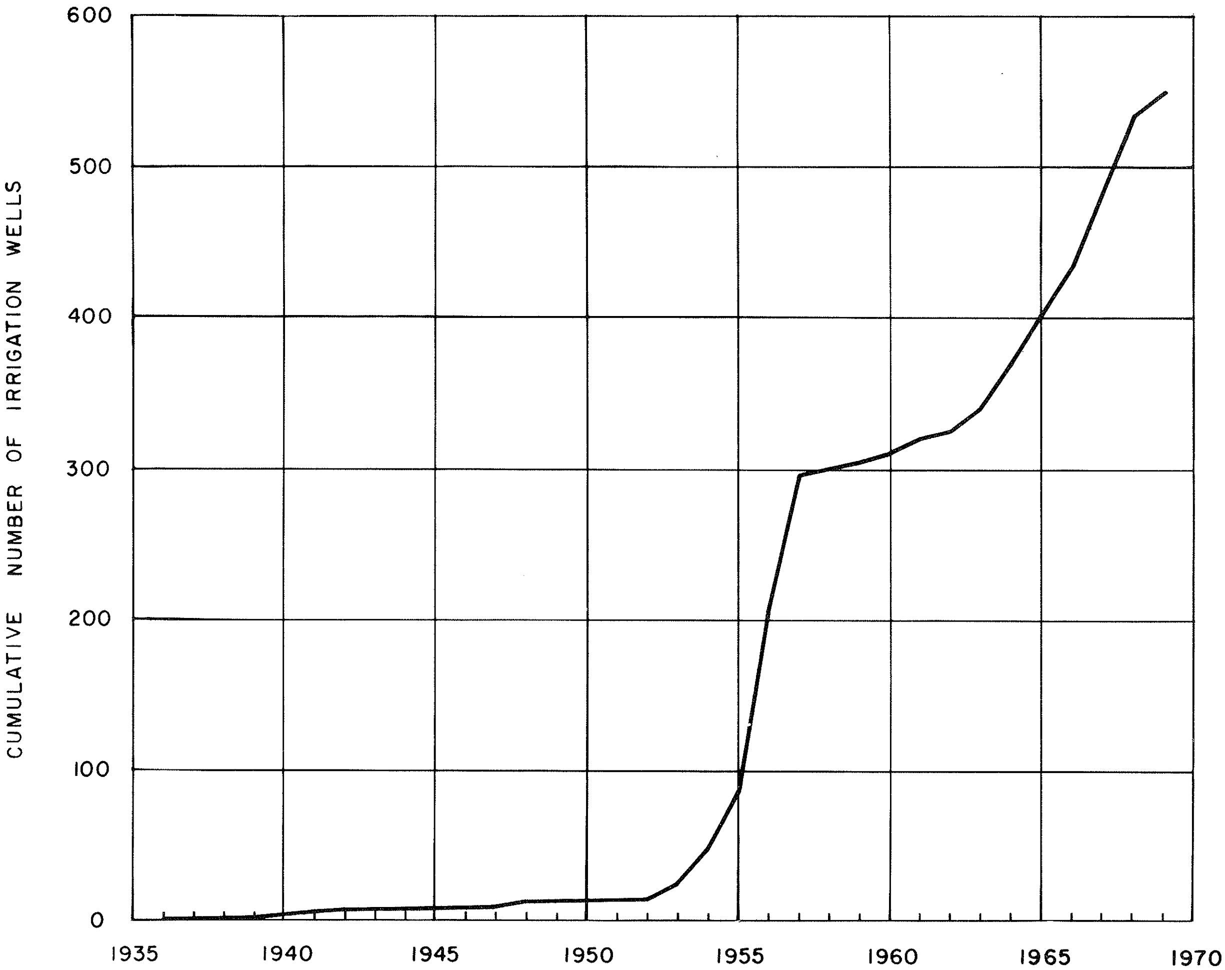
Using the data collected during the summer of 1968 and information compiled by the U. S. Weather Bureau and the State-Federal Division of Agricultural Statistics, the total irrigation pumpage for that season can be estimated.

The average amount of water pumped in 1968 by 31 tested wells was 76.8 acre-feet. Assuming this amount to be an average for all wells in the county, the 540 irrigation wells in Seward



HYDROGRAPH OF ROLFSMEIER IRRIGATION WELL
SEWARD COUNTY, NEBRASKA

FIGURE 3



IRRIGATION-WELL INSTALLATIONS
SEWARD COUNTY, NEBRASKA

FIGURE 4

County withdrew 42,000 acre-feet of water from storage.

Stallman (1968, p. 1-2) suggested an alternative method of calculation that attempts to acknowledge and take into account the effects of "land use patterns, aquifer characteristics, state of aquifer development, population density, use of surface water for irrigation, and a host of other variables." Sufficient information was available from 19 of the original 31 wells to perform the computations suggested by Stallman. For each of the 19 wells analyzed, the amount pumped was divided by the acres irrigated from that well. This pumpage per unit area for the 19 wells (0.83 acre-feet per acre) was then averaged and multiplied by the total irrigated acreage of the county. The resulting 46,000 acre-feet is greater than the 42,000 acre-feet calculated above.

Reed (1969, personal communication) has suggested another method to determine groundwater withdrawal by wells. This method is empirical and does not require well-discharge measurements. The only input data required are precipitation records and the number of irrigation wells in the area of interest. Reed made the following assumptions: (1) that the average water requirement for crops in this region ranges from 24 to 28 inches, (2) that approximately 60 percent of the annual precipitation falls during the growing season (from long-term weather records), and (3) that approximately 100 acres are irrigated per well (an assumption well-verified by the field study). Therefore, the amount of supplemental water (from wells) necessary for crop production is the difference between the crop requirement and

60 percent of the annual precipitation.

The average precipitation in Seward County in 1968 was about 29 inches. Of this, 17.4 inches (60 percent of 29 in.) was available for crop use. If 26 inches is assumed to be the average water requirement, 8.6 inches had to be provided by irrigation. The total quantity of water pumped in Seward County, then, is the product of the water requirement (8.6 inches), the number of acres irrigated per well (100), and the total number of wells (540). The result of this analysis suggests that 38,700 acre-feet of water was pumped. This quantity is reasonable when compared with the previously calculated quantities.

Judging from the above calculations, 42,000 acre-feet seems to be a reasonable estimate of the amount of groundwater pumped for irrigation. This quantity is near the mean of the three analyses and is a suitable estimate of groundwater withdrawal for water-management planning.

ECONOMIC BENEFITS FROM GROUNDWATER USE

The economic value of pump irrigation to agriculture has long been recognized, but until recently its benefits have not been studied extensively. These benefits have been most evident to individual irrigators. The segment of the economy which experiences secondary benefits from pump irrigation has not been cognizant of the economic impact of irrigation to the same degree as individual farm operators.

Utilization of new irrigation-management techniques has helped irrigators develop greater farming efficiency. Specialized equipment and techniques such as resistance blocks for measuring soil moisture, recirculation systems that use runoff from irrigated fields, and the use of underground delivery systems have enabled some individuals to be more efficient irrigators.

Because of the relatively small differences in the physical features of the irrigated areas of Seward County, the data gathered are representative for determining the economic aspects of groundwater irrigation. The farmers interviewed, except for five cases, farmed both irrigated and dry-land acreages. Regional differences in farming practices are minimized because both dry-land and irrigated acreages are under the same management influence.

Cost of Pumping Groundwater

The costs of pumping water for irrigation are similar to costs encountered in operating other equipment. Operational expenses for fuel and repairs are similar to those experienced in the operation of most mechanical equipment.

Items such as labor, fuel, and lubrication vary with the amount of time of operation and are classified as variable costs. The sum of fixed and variable costs is total costs of operation.

The annual depreciation on all equipment (wells, portable pumps, pipe, and pipe fittings) and the annual prorated expense for land leveling were considered to be fixed costs. Depreciation was calculated by using the straight-line method, and all equipment was considered to have a useful life of 20 years with no salvage value. Annual expenses for land leveling were computed at an assumed interest rate of seven percent and a perpetual life for the improvement. Engine repair costs were calculated by assuming a complete overhaul at the end of the first 10 years of service. The annual costs for these repairs were computed by assuming that annual payments were made into a hypothetical seven percent sinking fund. All values assumed above for useful life, salvage, and repair intervals were obtained from estimates prepared by the Department of Agricultural Engineering, University of Nebraska (1962).

Annual variable costs were calculated from estimates given by the individuals interviewed. Factors such as labor and lubrication costs were difficult for the farmers to estimate because of the tendency of these expenditures to overlap into other aspects of farm operation. For the most part, fuel and power expenses were obtained from personal records and power company billing schedules.

Some additional expenses were not considered in this study, such as annual expenses for equipment insurance, taxes, and electric or natural-gas installation charges. Most farmers could not determine what proportion of their taxes should be allocated to pumping equipment. Insurance costs were difficult to determine because of the "blanket-coverage" nature of many policies, and many farmers did not have insurance coverage. Power or natural-gas transmission costs were not computed because of variations resulting from distance factors and multiple farm uses of power or fuel. Some farmers had installed new equipment (such as a grain dryer or gas furnace) to take advantage of the new energy-delivery system.

Table 1 shows the various input costs associated with the operation of an irrigation well. Fixed costs are greater than variable costs in all but two cases. As Epp (1954) noted, this suggests that cost per acre-foot of water pumped decreases as the volume pumped increases because the fixed costs are distributed over more units. Relating the cost per acre-foot per foot of lift to quantity pumped shows how cost per unit pumped decreases with increased volume (Table 1). Factors such as well depth, pump efficiency, and pumping lift have been eliminated with this approach.

Average pumping costs per acre-foot ($19.60) in Seward County compare favorably with per acre-foot costs encountered in the Texas High Plains (a region of similar physiography and groundwater occurrence). Pump irrigation studies in that area indicate that greater quantities of groundwater are pumped per acre, and that the average cost per acre-foot is $15.61 (1968, p. 69). The cost per acre-foot of pumped water in Seward County is greater than the cost of water for irrigation in areas served by surface-water projects.

Benefits of Using Groundwater for Irrigation

To determine returns to the on-farm segment of the Seward County economy involves calculation of additional input expenses beyond those encountered on dry-land acreages. Farm operators provided sufficient information concerning farming practices on dry-land and irrigated acreages for comparison. In addition, the

Table 1. Input costs per well for pumping groundwater for irrigation in Seward County, Nebraska, 1968

Total lift (ft)	Acre-ft pumped	Fixed costs	Variable costs	Total costs	Total cost per acre-ft	Total cost per acre-ft per ft lift
110	96	$ 895	$ 747	$1642	$17.20	$0.15
53	16	360	108	468	29.40	0.56
110	146	464	499	963	6.60	0.06
120	42	452	1049	1501	35.70	0.30
109	49	538	420	958	19.60	0.18
112	64	668	393	1061	18.30	0.16
82	137	664	365	1029	7.50	0.09
93	38	415	260	675	17.50	0.19
91	72	787	653	1440	20.00	0.22
98	76	1400	910	2310	30.40	0.31
44	34	133	78	211	6.20	0.14
105	66	1037	903	1940	29.40	0.28
114	103	923	368	1291	12.50	0.11
98	105	863	785	1648	15.70	0.16
112	99	1550	1330	2880	29.10	0.26
88	42	420	320	740	17.60	0.20
Average		$ 723	$ 574	$1297	$19.60	$0.21

average crop yield and acreage devoted to a specific crop was obtained from Nebraska Agricultural Statistics, 1968.

Table 2 shows the cropping patterns and water use on irrigated and dry-land acreages. Corn and grain sorghum were chosen to compare irrigated and dry-land operations because together they are the crops grown on about 70 percent of the irrigated crop land. Sufficient data were not gathered on irrigated soybeans, corn silage, or alfalfa hay for making reliable comparisons of these crops.

Dry-land and irrigated acreage figures indicate that corn is cultivated on 59 percent of the irrigated acreage, but only 6.6 percent of the dry-land acreage. Comparison of corn yield (115 bushels per acre vs. 60 bushels per acre) indicates an increase in yield of 91 percent for irrigated corn. The percentage of grain sorghum acreage was greater in dry-land operations than in irrigated operations. This probably reflects the lower water requirement of sorghum and smaller increases in yield resulting from irrigation (95 bushels per acre vs. 64 bushels per acre).

The amount and frequency of application of irrigation water varies from crop to crop. The usual irrigation practice in 1968 was three applications of water for corn, one application for grain sorghum, and less than one for all other crops.

Additional costs associated with irrigated crop production were incurred primarily from those expenses shown in Table 3. As expected, costs for seed and fertilizer were substantially greater for irrigated corn than for dry-land corn. Irrigated grain sorghum shows the greatest difference in fertilizer costs

Table 2. Cropping patterns and water use on irrigated and dry-land acreages in Seward County, Nebraska, 1968

	Irrigated acreage				
	Acres[a]	% of all irrigated acres	Average yield bu per acre[a]	Acre-ft of water applied	Acre-ft of water applied per acre[c]
Corn	32,800	59.0	115	28,000	0.885
Grain sorghum	6,500	11.7	95	9,340	0.532
Other[b]	16,300	29.3	---	4,660	2.639
Totals	55,600	100.0			

	Dry-land acreage		
	Acres	% of all dry-land acres	Average yield by per acre
Corn	21,870	6.6	60
Grain sorghum	59,290	18.0	64
Other[d]	248,840	75.4	---
Totals	330,000	100.0	

[a] U.S.D.A., Nebraska Agricultural Statistics, 1968
[b] Includes corn silage, soybeans, alfalfa hay, and pasture
[c] Assumes three irrigations for corn, one irrigation for grain sorghum, and one-half irrigation for other crops
[d] Includes wheat, oats, rye, soybeans, barley, hay and alfalfa hay

Table 3. Average per acre input costs of irrigated and dry-land acreages in Seward County, Nebraska, 1968

	Seed	Fertilizer	Herbicide	Insecticide	Irrigation water	Total
Irrigated acreage						
Corn	$4.40	$11.60	$2.85	$2.78	$17.34	$38.97
Grain sorghum	2.46	11.35	2.00	1.25	10.42	27.48
Other	----	-----	----	----	7.45	-----
Dry-land acreage						
Corn	$2.55	$6.50	$2.80	$2.65	$0.00	$14.50
Grain sorghum	2.18	4.38	2.00	1.25	0.00	9.81
Other	----	----	----	----	0.00	-----

compared to dry-land grain sorghum. Seed costs for dry-land and irrigated grain sorghum were not significantly different since the plant density was similar for both dry-land and irrigated operations.

The cost of irrigation water was calculated by multiplying the amount of irrigation water applied per acre (Table 2) by $19.60, the cost per acre-foot of water pumped (Table 1). The highest water cost of all the crops studied was for corn.

Expenses incurred in machinery operation for planting, cultivation, and harvesting were not determined. Field expenses for fertilizer, herbicide, or insecticide applications were likewise omitted. The persons interviewed were unable to report the per-acre equipment costs for individual crops because of the many non-irrigation jobs performed. They suggested, however, that irrigated crops probably require greater field expenses than dry-land crops.

Table 4 presents a summary of the costs and returns of irrigated and dry-land corn and grain sorghum acreage. Total returns were calculated by assuming the irrigated and dry-land average per bushel production shown in Table 2. Market prices for corn and grain sorghum were assumed to be $1.05 per bushel and $1.60 per hundred-weight respectively. The costs shown are those discussed earlier in connection with Table 3.

The results show an increased per-acre return favorable to irrigation of $33.28 for corn and $13.33 for grain sorghum. The results are, however, representative of 1968 only. Examination of these data suggests that corn returns from irrigation vs. dry-

Table 4. Per acre costs and returns of irrigated and dry-land acreages in Seward County, Nebraska, 1968

	Corn[a]	Grain sorghum[b]
Irrigated acreage:		
Total returns	$120.75	$95.00
Total costs[c]	38.97	27.48
Net return	81.78	67.52
Dry-land acreage:		
Total returns	$ 63.00	$64.00
Total costs[c]	14.50	9.81
Net return	48.50	54.19

Increased per acre returns of irrigated acreage over dry-land acreage:

Corn	$33.28
Grain sorghum	$13.33

[a]Assumes corn price of $1.05 per bushel

[b]Assumes grain sorghum price of $1.60 per cwt

[c]Includes only costs of seed, fertilizer, herbicide, insecticide, and those costs associated directly with irrigation well ownership and operation

land operations are more than twice those for grain sorghum. These results account, at least partially, for the large proportion of irrigated acreage devoted to corn production.

SUMMARY AND CONCLUSIONS

Use of groundwater for irrigation has certain effects on both the hydrology and economy of Seward County. Groundwater withdrawals (42,000 acre-feet in 1968) have resulted in a declining water table (about 3 to 10 feet in the past 10 to 15 years) in most areas of the county where water is pumped for irrigation. The result noticed by irrigators has been increased pumping lifts and, in some cases, a need for deeper pump settings in existing wells. To date, the declining water table has not caused a significant decline in well yields. Many persons are concerned, however, that over extended time, the water level in some wells may decline enough to make groundwater pumping uneconomical, at least by current standards.

Use of groundwater has increased economic returns both to irrigators and to that segment of the community supplying additional agricultural inputs. Both the results of this study and the irrigated-acreage totals shown in Table 2 indicate that of all crops irrigated in Seward County, corn produces the greatest economic benefit.

This study did not consider irrigation benefits to crops other than corn and grain sorghum; however, benefits to production of other phases of agriculture such as livestock or silage production undoubtedly exist.

No attempt has been made in Seward County to reinvest some of the increased economic returns into research or facilities to replenish diminishing groundwater supplies. Basic studies of ways to utilize more efficiently the groundwater resource of the county should be undertaken because the economy of the county is, at least partially, dependent upon its groundwater supply. Additional study should be conducted to determine long-term consumptive use, hydrologic characteristics of the aquifer, changes in water quality, and to evaluate water-level changes more precisely. The economic worth of the groundwater supply, in terms of marginal values, should be evaluated for the purpose of deciding the magnitude and extent of future resource investments.

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APPENDIX

Test Procedure Used in Measurement of Discharge and Drawdown

Arrangements were made with farm operators to measure a given well after it had been in operation continuously for at least two days. An equilibrium condition of stabilized discharge and drawdown was assumed to have taken place after this length of time.

Upon arriving at a well site, the well was shut down and a Sparling flow meter was installed. The well was then restarted and allowed to operate at normal operating conditions for 30 minutes. After 30 minutes had passed, a 6-minute timed measurement of discharge from the well was recorded. During this 6 minutes the depth to water in the well was measured, using an electric depth-to-water level indicator. Also, in the case of an electric or natural-gas operated well, the energy meter was observed in operation and the necessary constants recorded for later calculation of operating hours.

Discharge calculations were made in the field and rounded to the nearest five gallons per minute. Since all measurements were in the range of 285 to 1,520 gallons per minute, errors in rounding are considered to be negligible, inasmuch as the flow meter manufacturer suggests an error of plus or minus two percent.

Table 5. Record of measured irrigation wells in Seward County, Nebraska, 1968

Location	Static Water Level (Ft)	Discharge (GPM)	Drawdown (Ft)	Pump. Hrs.	Pumpage (Ac. Ft)
09-01-07ab	42.06	540	11.90	160.0	15.91
09-01-28aa	84.74	1100	8.14	206.0	41.73
09-03-03bd	64.90	690	---	342.5	43.53
09-03-20ad	74.54	700	16.38	560.0	72.19
10-01-01dd	95.20	735	18.80	763.0	103.27
10-01-04db	95.66	585	15.88	593.0	63.88
10-01-24ab	84.33	640	---	773.0	91.10
10-01-25db	83.74	740	24.43	625.0	85.17
10-02-08da	73.80	700	34.66	378.0	48.72
10-02-09cb	69.05	670	29.45	615.0	75.88
10-02-10ba	71.16	885	19.59	546.0	88.98
10-02-19bb	77.95	785	31.80	707.0	102.20
10-02-20bd	78.76	1150	19.07	497.7	105.40
10-02-21d	75.15	800	17.35	458.0	67.47
10-02-24ca	66.03	1170	20.64	703.0	151.46
10-02-25da	62.38	1290	20.25	575.0	136.59
10-02-29da	77.16	985	34.84	547.6	99.33
10-03-07ba	60.18	420	28.07	548.5	42.42
10-03-29da	64.00	500	28.75	411.0	37.84
11-01-05ad	77.48	1520	27.06	251.0	70.26
11-01-16dd	89.30	920	14.78	454.0	76.91
11-02-09cb	80.35	585	15.28	1130.0	121.73
11-02-18bc	82.21	860	26.79	922.5	146.09
11-02-21da	80.90	550	23.77	647.0	65.53
11-02-28cb	77.20	640	36.20	598.0	70.48
11-02-36bb	80.72	870	21.70	953.0	152.68
12-01-06bb	100.12	1150	---	201.4	42.65
12-01-08db	81.00	975	37.38	376.0	67.51
12-01-23bb	73.65	625	45.60	366.0	42.12
12-01-36aa	13.08	285	29.12	643.0	33.75
12-03-16ca	87.57	340	20.22	361.0	22.60